FACULTY OF ELECTRICAL ENGINEERING

SUBJECT CARD

Name in Polish:	**Cyfrowe przetwarzanie sygnałów w układach automatyki elektroenergetycznej**
Name in English:	**Digital Signal Processing for Protection and Control**
Main field of study (if applicable):	**Electrical Engineering**
Specialization (if applicable):	**Control in Electrical Power Engineering**
Level and form of studies:	**2nd level, full-time**
Kind of subject:	**obligatory**
Subject code:	**ELR052134**
Group of courses:	**NO**

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU):	30			30	
Number of hours of total student workload (CNPS):	60			60	
Form of crediting:	examination			crediting with grade	
For group of courses mark (X) final course:					
Number of ECTS points:	2			2	
including number of ECTS points for practical (P) classes :				2	
including number of ECTS points for direct teacher-student contact (BK) classes:	1.40			1.40	

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Knowledge of basics of power system control, digital signal processing and numerical methods.
2. Practical skills of using MATLAB and ATP-EMTP software.

SUBJECT OBJECTIVES

C1. Acquaintance of knowledge related to digital power system protection and control systems including: digital filtration, measurement of criteria values and decision making.

C2. Practical skills to analyze and design of both hardware structure and software of digital control and protection for power systems, with special consideration to algorithms of digital filtration, measurement of criteria values and decision making.

SUBJECT LEARNING OUTCOMES

relating to knowledge:

PEU_W01 Possesses knowledge related to structure of digital power system control and protection systems as well as knowledge related to processing of continuous signals, their discretization and processing of digital signals.

PEU_W02 Possesses knowledge related to digital filtering, algorithms of criteria values measurement, their accuracy and dynamics as well as possibilities of measurement errors elimination.

PEU_W03 Possesses knowledge related to deterministic and probabilistic decision processes, fundamentals of adaptive systems and structure of multi-criteria devices.

relating to skills:

PEU_U01 Is able to model and evaluate operation of the measurement path and A/D conversion units as well as to perform analysis and synthesis of digital recursive and non-recursive filters.

PEU_U02 Is able to model and evaluate operation of digital algorithms for protection criteria measurement.

PEU_U03 Is able to model and evaluate operation of the basic decision making algorithms for decision making in power system protection and control.

relating to social competences:

PEU_K01 Is able to carry out a complex engineering project in a competent way.

PROGRAMME CONTENT		
Form of classes - lecture		**Number of hours:**
Lec 1	Introduction. Setting rules of course crediting. Historical perspective, development of analog and digital power system control systems, reasons for and benefits of digital control, advantages of digital implementation.	2
Lec 2	Mathematical basis for control and protection algorithms: complex Fourier series, Fourier transform, Discrete Fourier transform, Z-transform, analog and discrete integration.	2
Lec 3	Analog filters: standard low-pass approximations, frequency and time response of the filter, analog filter design, frequency band transformation.	2
Lec 4	Analog to digital converters, multiplexer and analog memory, quantization time and errors, Shannon sampling theorem, practical sampling rates. Classification of digital filters.	2
Lec 5	Design of recursive filters using impulse invariant techniques. Design of recursive filters using frequency prewarping and the bilinear transformation, problems of quantization and round-off errors.	2
Lec 6	Design of non-recursive digital filters using a window function, commonly used FIR filter window functions and associated frequency responses.	2
Lec 7	Signal orthogonalization algorithms: single & double delay methods, FIR orthogonal filters, correlation, least squares estimation technique.	2
Lec 8	Signal magnitude estimation: digital integration methods, orthogonal components based methods, correlation, detailed algorithms.	2
Lec 9	Measurement of other power system quantities: algorithms of estimation of active and reactive power, impedance components, signal phase, digital estimation of power system frequency and frequency deviation.	2
Lec 10	Measurements in dynamic state of estimation, measurement error sources (signal distortion, harmonics, fundamental frequency deviation, ...).	2
Lec 11	Influence of current transformers on the quality of criteria values calculation. Methods od CT saturation detection and correction of distorted secondary current.	2
Lec 12	Special algorithms. Application of wavelet transform for detection of high impedance faults.	2
Lec 13	Decision making process, decision regions and borders, deterministic and probabilistic decision making methods.	2
Lec 14	Adaptive control and protection systems, multi-criteria systems, integrated measurement, control and protection systems.	2
Lec 15	Wide area measurements for power system protection and control.	2
	Total hours:	**30**

Form of classes - project		**Number of hours:**
Proj 1	Introduction. Setting rules of course crediting. Acquaintance with lab stands and available software.	2
Proj 2	Design and evaluation of signal pre-processing and A/D conversion units.	4
Proj 3	Synthesis and analysis of digital IIR and FIR filters.	4
Proj 4	Quality evaluation of selected methods of digital estimation of signal magnitude.	4
Proj 5	Assessment of digital algorithms for power and impedance components measurement.	4
Proj 6	Evaluation of digital algorithms for frequency measurement.	2
Proj 7	Analysis of digital algorithms for symmetrical components extraction.	2
Proj 8	Design and evaluation of adaptive algorithms for measurement of selected protection criteria.	4
Proj 9	Evaluation of selected methods and algorithms of decision making.	2
Proj 10	Reserve date, accounting for the executed projects.	2
	Total hours:	**30**

TEACHING TOOLS USED
N1. Informative lecture.
N2. Matlab and ATP-EMTP programmes.
N3. Project presentation.

EVALUATION OF SUBJECT LEARNING OUTCOMES ACHIEVEMENT		
Evaluation *F – forming (during semester)* *P – concluding (at semester end)*	**Educational effect number**	**Way of evaluating educational effect achievement**
F1(W)	PEU_W01 PEU_W02 PEU_W03	Participation in the course.
F2(W)	PEU_W01 PEU_W02 PEU_W03	Final examination.
P(W)	P = 0,1F1 + 0,9F2	
F1(P)	PEU_U01 PEU_U02 PEU_U03 PEU_K01	Activity during the classes.
F2(P)	PEU_U01 PEU_U02 PEU_U03 PEU_K01	Presentation of the project done.
P(P)	P = 0,2F1 + 0,8F2	

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] Rebizant W., Szafran J., Wiszniewski A., Digital signal processing in power system protection and control, Springer, London 2011.
[2] Rebizant W., Wiszniewski A., Digital signal processing for protection and control, Skrypt PWr, Wrocław 2011
[3] Ungrad H., Winkler W., Wiszniewski A., Protection techniques in electrical energy systems, Marcel Dekker Inc. New York, Basel, Hong Kong 1995
[4] Jackson L.B., Digital filters and signal processing, Kluwer Academic Publishers, Boston 2002.

SECONDARY LITERATURE:

[1] Szafran J., Wiszniewski A., „Algorytmy pomiarowe i decyzyjne cyfrowej automatyki elektroenergetycznej”, WNT, Warszawa 2001
[2] Winkler W., Wiszniewski A, „Automatyka zabezpieczeniowa w systemach elektroenergetycznych”, WNT, Warszawa 2004
[3] Wiszniewski A., „Algorytmy pomiarów cyfrowych w automatyce elektroenergetycznej”, WNT, Warszawa 1990

SUBJECT SUPERVISOR

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